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Prevalence and antimicrobial susceptibility of *Salmonella* spp. isolates from US cattle in feedlots in 1999 and 2000

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ABSTRACT

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Aims: Faecal samples from cattle in US feedlots were evaluated for the presence of *Salmonella*. When *Salmonella* isolates were recovered the antimicrobial resistance patterns were determined.

Methods and Results: Faecal samples were collected from pen floors in 73 feedlots in 12 states during the period from October 1999 to September 2000. Pens of cattle selected for sampling were those that had been in the feedlot for the shortest period of time, the longest period of time and a randomly selected pen from the remaining pens. Faecal samples were cultured for *Salmonella* spp. and all *Salmonella* isolates were categorized by serotype. The susceptibilities of all isolates were determined using a panel of 17 antimicrobials. Overall, 6·3% (654/10 417) of the samples cultured positive for *Salmonella* spp. and 22·2% (94/422) of pens and 50·7% (37/73) of feedlots had one or more positive samples. There was little difference in the proportion of positive samples from short-fed (6·1%, 212/3482), random (6·4%, 217/3400) and long-fed (6·4%, 224/3485) pens of cattle. One of two pens of cattle that could not be attributed to a pen type had a single positive sample (2·0%, 1/50). Samples collected during the period of April to June (6·8%, 209/3054) and July to September (11·4%, 286/2500) were more likely to be positive than those collected during October to December (4·0%, 73/1838) and January to March (2·8%, 86/3025). The most common serotypes of *Salmonella* were dissimilar from those that are typically seen in human illness and cattle illness. The majority of isolates (62·8%, 441/702) were sensitive to all of the antimicrobials tested. Resistance was most frequently observed to tetracycline (35·9%, 252/702) followed by streptomycin (11·1%, 78/702), ampicillin (10·4%, 73/702) and chloramphenicol (10·4%, 73/702). Multiple resistance (resistance to ≥2 antimicrobials) was observed for 11·7% (82/702) of the isolates.

Conclusions: *Salmonella* was isolated at low frequency from faeces of feedlot cattle and the serotypes were not those commonly associated with human illness. In addition most of the *Salmonella* isolates were sensitive to all the antimicrobials tested.

Significance and Impact of the Study: This study contributes to understanding the ecology of *Salmonella* in cattle feedlots and the prevalence of resistance among potential food-borne pathogens.

Keywords: antimicrobial resistance, cattle, feedlot, *Salmonella*.

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INTRODUCTION

Salmonella spp. are widely distributed in the digestive tracts of humans and animals (Grimont *et al.* 2000). To the extent that the environment is contaminated with faecal material from humans and animals, *Salmonella* spp. are also found there. *Salmonella* spp. are a significant cause of human and animal illness (Jensen and Mackey 1979; Smith 1990; Mead *et al.* 1999). In some cases, human illness is caused by *Salmonella* spp. that are food-borne. Food-borne *Salmonella* infections can originate with food handlers or other sources of contamination during the processing and distribution of products. Faecal contamination can also occur during the slaughter process. Numerous interventions have been implemented in harvest and processing facilities to limit the contamination of carcasses with potential food-borne pathogens (Bacon *et al.* 2000, Sofos *et al.* 1999). However, as there is not a definitive kill step of pathogens in the harvest and processing chain with the exception of cooking, most of the interventions operate on the expectation of a percentage reduction in the numbers of bacteria on the carcass. As such, preharvest interventions to lower the load of potential food-borne pathogens in faeces of animals presented for harvest are thought to offer opportunities to mitigate the risk of contaminated product. Understanding the prevalence and distribution of *Salmonella* spp. in food animals and determining management strategies associated with lower prevalence is key to decreasing the risk of high pathogen loads at harvest. One previous study has evaluated the prevalence and distribution of *Salmonella* spp. in feedlot cattle in the US in 1994 (Fedorka-Cray *et al.* 1998). In that study, *Salmonella* was more common in pens of cattle that had been in the feedlot a longer period of time and in feedlots from the southern part of the US. Dietary factors associated with presence of *Salmonella* in pens were feeding of tallow and feeding whole cottonseed or cottonseed hulls (Losinger *et al.* 1996).

In addition to concern about the presence of *Salmonella* spp. as a potential food-borne pathogen, concern has also been raised about the human health impact of presence of genetic determinants for antimicrobial resistance that can be transferred among these organisms. The presence of antimicrobial resistance determinants have the potential to adversely affect human health by causing illness that is more difficult to treat because of the resistance profile of the organism. Additionally, the resistant organism may act as a donor of the resistance determinant to another pathogen in the human intestinal tract, or act as a donor of the resistance determinant to human commensal flora of the intestinal tract which may later be associated with disease or in turn supply the resistance gene to another pathogen (Salyers 1995).

The objectives of this study were to (i) compare the distribution of *Salmonella* in feedlot cattle to that seen previously and evaluate trends across time, (ii) describe patterns of shedding associated with season and time in the feedlot, (iii) evaluate dietary and management factors associated with presence of *Salmonella* in feedlot cattle faeces, (iv) monitor trends in antimicrobial resistance among *Salmonella* isolates from feedlot cattle, and (v) evaluate factors associated with antimicrobial resistance among *Salmonella* from feedlot cattle.

MATERIALS AND METHODS

Sample source

Feedlots (A feedlot is a confinement operation usually consisting of multiple open pens where young cattle are fed a high energy diet until they reach the desired slaughter weight. Typically, cattle are not housed during any part of the year while in feedlots.) participating in a study of health and management conducted by the USDA's National Animal Health Monitoring System were solicited to allow the collection of faecal samples for bacteriologic culture for *Salmonella* spp. A target of 75 participating feedlots was set based on availability of laboratory resources. The targeted feedlots were distributed to the 12 states (Arizona, California, Colorado, Idaho, Iowa, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas and Washington) participating in the study based on the number of feedlots in each state with at least 1000 head capacity. Each feedlot was visited once in the period from October 1999 to March 2000, and again in the period from April 2000 to September 2000. At each visit the pens of cattle that had been at the feedlot the shortest amount of time, the longest amount of time and a randomly chosen pen were selected for sampling. Within each pen 25 fresh faecal samples (*ca* 25 g) were collected from the pen floor throughout the pen using individual tongue depressors for placing each sample into whirlpak bags. Samples were collected from the top of the faecal pat to minimize possible contamination from the pen floor. Samples were shipped with ice packs for overnight delivery to the laboratory.

Bacteriologic culture methods

Each sample was evaluated by bacteriologic culture for *Salmonella* spp. using methods described previously (Wells *et al.* 2001). Approximately 1 g of faeces from each sample was placed into each of two culture media: tetrathionate broth (Tet) and gram negative Hajna broth (GN). All cultures were incubated overnight at 37°C. At 24 h, *ca* 100 μl from the GN culture was transferred into Rappaport R-10 medium (R-10) (GN-R). At 48 h, 100 μl was also transferred from the Tet culture into R-10 (T48-R). All GN-R and T48-R media were incubated overnight at 37°C, then plated on brilliant green agar with sulphadiazine (BGS)

and xylose–lysine tergitol 4 (XLT4). All plates were incubated overnight at 37°C. At least three colonies having the typical appearance of *Salmonella* were picked to triple sugar iron and lysine iron agar slants. All slants were incubated overnight at 37°C. Presumptive positive isolates were serogrouped using serogroup specific typing sera (Difco Laboratories, Detroit, MI, USA) and sent to the National Veterinary Services Laboratories (NVSL) for serotyping. Only one isolate per sample was serotyped if all three isolates were of the same serogroup. All isolates from a single faecal sample with different serogroups were serotyped. *Salmonella* Typhimurium isolates that were resistant to ampicillin, chloramphenicol, streptomycin, sulphamethoxazole and tetracycline were phage typed at the NVSL using methods from the Central Public Health Laboratory (London, UK) (Anderson *et al.* 1977).

Antimicrobial susceptibility methods

Each *Salmonella* isolate was tested for susceptibility to a custom made panel of 17 antimicrobial drugs using a semi-automated testing system (Sensititre; TREK Diagnostics, Westlake, OH, USA). The minimum inhibitory concentration for each isolate was determined. Where possible each isolate was classified as susceptible, intermediate or resistant according to standards used to classify isolates by the National Committee on Clinical Laboratory Standards (NCCLS 1999a,b). Otherwise, breakpoint interpretations used in the National Antimicrobial Resistance Monitoring System were used (FDA, USDA and CDC 1998).

Statistical analysis

The proportion of samples, pens and feedlots with a positive bacteriologic culture for *Salmonella* spp. was determined. Pens and feedlots were considered positive if *Salmonella* was cultured from one or more of the individual samples. Additional analysis by type of pen (time on feed), season of sample collection and geographic region (southern: Arizona, California, Colorado, New Mexico, Oklahoma, Texas, and northern: Idaho, Iowa, Kansas, Nebraska, South Dakota and Washington) were conducted. Sampling periods were divided into four intervals; October to December, January to March, April to June and July to September. Feedlots were classified with regard to size using both capacity and annual placements. Feedlots with a one-time capacity of 1000–7999 head were small capacity yards compared with those with capacity for 8000 or more head. Based on the actual number of cattle placed on feed from July 1998 to June 1999, placement categories of ≤10 000 head, 10 001–25 000 head, 25 001–50 000 head and >50 000 head were created. Prevalence was compared univariately with a log-likelihood chi-square test adjusted for the clustering of samples by pen and clustering of pens by feedlot (Shah *et al.* 1996). $P < 0{\cdot}05$ was statistically significant.

RESULTS

Faecal samples were collected in 70 feedlots in both sampling periods while three additional feedlots collected samples once. Overall, *Salmonella* was recovered from 6·3% (654/10 417) of samples. By pen type, 6·1% (212/3482), 6·4% (217/3400) and 6·4% (224/3485) samples were positive from short-fed, random and long-fed pens, respectively. The differences in prevalence by pen type were not significant ($P = 0{\cdot}95$). The average number of days the cattle had been in the feedlot was 19·2 for short-fed pens, 91·7 for random pens and 180·2 for long-fed pens. More samples (7·7%, 406/5279) were positive from the southern region than from the northern region (4·8%, 248/5138) however this difference was not significant statistically ($P = 0{\cdot}42$). The lowest proportion of positive samples was detected in period two (January to March 2000, 2·8%, 86/3025) followed by period one (October to December 1999, 4·0%, 73/1838). The highest sample prevalence was in period four (July to September 2000, 11·4%, 286/2500) while period three was intermediate (April to June 2000, 6·8%, 209/3054). The *P*-value for a difference by quarter was 0·05. When the data were collapsed to reflect a 'cold' season (periods 1 and 2) and a 'warm' season (periods 3 and 4), there was a significant difference in prevalence ($P = 0{\cdot}008$). There was no significant difference ($P = 0{\cdot}38$) in prevalence of positive samples for small capacity feedlots (7·8%) compared with large capacity feedlots (4·7%). There was a significant difference ($P = 0{\cdot}004$) in the prevalence by size of feedlot based on annual placements. The prevalence was 7·9, 7·0, 0·3 and 5·8%, respectively, for the smallest to largest feedlots. Sample prevalence within a pen ranged from 0 to 100%.

Of the 422 pens where samples were collected, 22·2% (94/422) had one or more positive samples. For short-fed pens, 25·4% (36/142) were positive, while 21·9% (30/137) of random pens and 19·1% (27/141) long-fed pens were positive. One of two pens of cattle that could not be attributed to a pen type had a positive sample. The majority of the positive pens (58·5%, 55/94) had one to five positive samples while 16·0, 7·4, 10·6 and 7·4% had six to 10, 11–15, 16–20, 21–25 positive samples, respectively.

Among the 73 feedlots where samples were collected in one or both sampling periods, 50·7% (37/73) had one or more positive samples. The percentage of feedlots with a positive sample was not different ($P = 0{\cdot}20$) by time period: period one, 44·0% (11/25), period two, 26·2% (11/42), period three, 29·3% (12/41) and period four, 45·7% (16/35).

The 654 positive faecal samples yielded 713 *Salmonella* isolates. Although 72·0% (511/713) of isolates represented five *Salmonella* serotypes, there was a total of 29 serotypes

Table 1 Percentage of *Salmonella* isolates from feedlot pen floor samples by serotype

Serotype	Isolates		Feedlots	
	n	%	*n*	%
Agona	40	5·6	4	5·5
Anatum	195	27·4	12	16·4
Braenderup	3	0·4	3	4·1
Carrau	1	0·1	1	1·4
Cerro	7	1·0	2	2·7
Cubana	1	0·1	1	1·4
Drypool	13	1·8	1	1·4
Dublin	2	0·3	2	2·7
Give	1	0·1	1	1·4
Havana	1	0·1	1	1·4
Infantis	4	0·6	1	1·4
Kentucky	57	8·0	9	12·3
Manila	2	0·3	1	1·4
Mbandaka	36	5·1	5	6·8
Meleagridis	3	0·4	2	2·7
Montevideo	127	17·8	9	12·8
Muenchen	6	0·8	3	4·1
Muenster	18	2·5	1	1·4
Newington	12	1·7	3	4·1
Newport	63	8·8	4	5·5
Othmarschen	1	0·1	1	1·4
Reading	69	9·7	2	2·7
Schwarzengrund	1	0·1	1	1·4
Senftenberg	1	0·1	1	1·4
Taksony	5	0·7	2	2·7
Tennessee	5	0·7	3	4·1
Thompson	2	0·3	2	2·7
Typhimurium	19	2·7	6	8·2
Untypable	16	2·2	8	10·9
Multiple serotypes	2	0·3	2	2·7
Total	713	100·0		

identified (including 16 isolates that were untypable and two samples with multiple serotypes) (Table 1). The most common serotype of *Salmonella* isolated was *S.* Anatum (27·4%, 195/713) followed by *S.* Montevideo (17·8%, 127/713), *S.* Reading (9·7%, 69/713), *S.* Newport (8·8%, 63/713) and *S.* Kentucky (8·0%, 57/713). While three of the five most common serotypes were identified in all time periods of sampling, *S.* Newport and *S.* Reading were only identified in the periods from April to September.

Seven hundred and two of 713 isolates were tested for susceptibility. Resistance was most common to tetracycline (35·9%, 252/702). One-quarter (24·5%, 172/702) of the isolates were resistant only to tetracycline while multiple resistance (resistance to ≥2 antimicrobials) was observed for 11·7% (82/702) isolates. Fewer isolates were resistant to streptomycin (11·1%, 78/702), ampicillin (10·4%, 73/702) and chloramphenicol (10·4%, 73/702) (Table 2). Less than

Table 2 Percentage of *Salmonella* isolates from feedlot cattle by level of resistance to various antimicrobics

Antimicrobial	Susceptible (%)	Intermediate (%)	Resistant (%)
Amikacin (Am)	100·0	0·0	0·0
Amoxicillin/clavulanic acid (Amo)	90·2	0·4	9·4
Ampicillin (Amp)	89·3	0·3	10·4
Apramycin (Apr)	99·7	0·3	0·0
Cefoxitin (Cefo)	90·3	0·4	9·3
Ceftiofur (Ceft)	90·9	0·0	9·1
Ceftriaxone (Ceftri)	93·0	6·4	0·6
Cephalothin (Ceph)	90·6	0·1	9·3
Chloramphenicol (Chlor)	89·6	0·0	10·4
Ciprofloxacin (Cip)	100·0	0·0	0·0
Gentamicin (Gen)	99·9	0·1	0·0
Kanamycin (Kan)	98·7	0·0	1·3
Naladixic Acid (Nal)	99·7	0·0	0·3
Streptomycin (Str)	88·9	0·0	11·1
Sulphamethoxazole (Sulph)	90·6	0·0	9·4
Tetracycline (Tet)	64·0	0·1	35·9
Trimethoprim/sulphamethoxazole (Tris)	95·0	0·0	5·0

10% of the isolates were resistant to each of the other antimicrobials. None of the isolates were resistant to amikacin, apramycin, ciprofloxacin or gentamicin. Overall, 62·9% (441/702) of the isolates were sensitive to all the antimicrobials in the panel (Table 3).

Resistance was more common among some serotypes than others. Nearly all (98·3%, 58/59) of the *S.* Newport isolates were resistant to one or more antimicrobials as were 95·7% (66/69) of the *S.* Reading, and 68·4% (13/19) of the *S.* Typhimurium isolates. Only two of 123 (1·6%) of *S.* Montevideo isolates were resistant to any antimicrobial. Among the *S.* Typhimurium isolates three had a resistance pattern that included ampicillin, chloramphenicol, streptomycin, sulphamethoxazole and tetracycline (R type ACSSuT) which has been associated with an epidemic form of *S.* Typhimurium definitive phage type (DT) 104 (Evans and Davies 1996; Wray and Davies 1996). All of these isolates were *S.* Typhimurium DT104.

There was some clustering of isolates by pen and by feedlot. The 25 samples that were culture positive for *S.* Newport with antibiograms of amo/amp/cefo/ceft/ceph/chlor/str/sulph/tet were from five pens of cattle on two operations (Table 4). There were 22 *S.* Newport isolates with the antibiograms of amo/amp/cefo/ceft/ceph/chlor/str/sulph/tet/tris and these isolates were derived from six pens of cattle on three operations. All 69 isolates of *S.* Reading were from six pens of cattle on a single operation.

Among the 91 pens with *Salmonella* isolates that were tested for antimicrobial susceptibility, 47·3% (43/91) had

Table 3 Resistance patterns among 702 *Salmonella* isolates from feedlot cattle

Resistance pattern	*Salmonella* isolates	
	Tested (*n*)	Susceptible (%)
None – sensitive to all antimicrobics	441	62·8
Tet	172	24·5
Amo, Amp, Cefo, Ceft, Ceph, Chlor, Str, Sulph, Tet	25	3·6
Amo, Amp, Cefo, Ceft, Ceph, Chlor, Str, Sulph, Tet, Tris	23	3·3
Chlor, Str, Sulph, Tet	4	0·6
Str	3	0·4
Amp, Chor, Str, Sulph, Tet	3	0·4
Sulph, Tet	2	0·3
Amo, Amp, Cefo, Ceft, Ceph, Chlor, Str, Tet	2	0·3
Amo, Amp, Cefo, Ceft, Ceph, Chlor, Str, Tet, Tris	2	0·3
Amo, Amp, Cefo, Ceft, Ceph, Chlor, Kan, Str, Tet, Tris	2	0·3
Tet, Tris	1	0·1
Sulph, Tet, Tris	1	0·1
Str, Tet	1	0·1
Nal	1	0·1
Kan, Str, Sulph, Tet	1	0·1
Cefo	1	0·1
Amp	1	0·1
Amp, Kan, Str, Tet	1	0·1
Amp, Kan, Nal, Sulph	1	0·1
Amp, Chlor, Str, Tet	1	0·1
Amp, Ceph	1	0·1
Amo, Cefo, Ceph	1	0·1
Amo, Amp, Ceph, Chlor, Tet	1	0·1
Amo, Amp, Ceft, Ceph, Chlor, Str, Sulph, Tet, Tris	1	0·1
Amo, Amp, Cefo Ceph, Chlor, Str, Tet	1	0·1
Amo, Amp, Cefo Ceph, Chlor, Str, Tet, Tris	1	0·1
Amo, Amp, Cefo Ceph, Chlor, Kan, Str, Tet	1	0·1
Amo, Amp, Cefo Ceph, Chlor, Kan, Str, Tet, Tris	1	0·1
Amo, Amp, Cefo Ceph, Chlor, Kan, Str, Sulph, Tet	1	0·1
Amo, Amp, Cefo, Ceft, Ceftri, Ceph, Chlor, Str, Tet	1	0·1
Amo, Amp, Cefo, Ceft, Ceftri, Ceph, Chlor, Str, Tet, Tris	1	0·1
Amo, Amp, Cefo, Ceft, Ceftri, Ceph, Chlor, Str, Sulph, Tet, Tris	1	0·1
Amo, Amp, Cefo, Ceft, Ceftri, Ceph, Chlor, Kan, Str, Sulph, Tet, Tris	1	0·1
Total	702	100

non-resistant isolates. The percentage of pens with 0·1–9·9, 10·0–24·9, 25·0–59·9, 50·0–74·9 and 75·0% or more of the isolates resistant to one or more antimicrobials was 5·5% (5/91), 3·3% (3/91), 5·5% (5/91), 7·7% (7/91) and 30·8% (28/91), respectively.

DISCUSSION

Prevalence

The prevalence of samples culture positive for *Salmonella* was similar to that observed in a previous study of feedlot cattle (Fedorka-Cray *et al.* 1998). In that study, samples were collected in the fall of 1994 and the overall prevalence of positive samples was 5·5% compared with 6·3% for the current study. In the current study, the sample culture positive prevalence of short-fed vs long-fed cattle, 6·1 and 6·4%, respectively, was closer than seen previously when 3·5 and 7·4% of samples were culture positive from short- and long-fed pens, respectively. Factors that may have affected this difference include sampling of different operations and pens, sampling at different times of the year, and ecologic changes. Using data from the current study only from the October to December time period (when the samples for the 1994 study were collected) the prevalence of positive samples from short- and long-fed pens was 2·9% (18/621) and 4·5% (28/625), respectively.

Table 4 Resistance of *Salmonella* by serotype

Serotype	Isolates (*n*)	Antimicrobial resistant (*n*)	Resistance pattern	Pens (*n*)	Feedlots (*n*)
Agona	40			8	4
	35	0		6	2
	2	11	Amo, Amp, Cefo, Ceft, Ceph, Chlor, Kan, Str, Sulph, Tet, Tris	1	1
	1	4	Chlor, Str, Sulph, Tet	1	1
	1	10	Amo, Amp, Cefo, Ceftri, Ceph, Chlor, Kan, Str, Tet, Tris	1	1
	1	11	Amo, Amp, Cefo, Ceft, Ceftri, Ceph, Chlor, Kan, Str, Tet, Tris	1	1
Anatum	194			37	12
	107	0		27	9
	81	1	Tet	21	7
	1	1	Str	1	1
	1	2	Str, Tet	1	1
	1	2	Amp, Ceph	1	1
	1	5	Amo, Amp, Cefo, Chlor, Tet	1	1
	1	9	Amo, Amp, Cefo, Ceft, Ceph, Chlor, Kan, Str, Tet	1	1
	1	10	Amo, Amp, Cefo, Ceft, Ceph, Chlor, Kan, Str, Sulph, Tet	1	1
Braenderup	3	0		3	3
Carrau	1	0		1	1
Cerro	7			3	2
	6	0		3	2
	1	1	Tet	1	1
Cubana	1	0		1	1
Drypool	13	0		4	1
Dublin	1	4	Amp, Kan, Str, Tet	1	1
Give	1	0		1	1
Havana	1	0		1	1
Infantis	4			1	1
	3	0		1	1
	1	1	Cefo	1	1
Kentucky	56			21	9
	41	0		14	7
	10	1	Tet	5	3
	2	1	Str	1	1
	1	1	Nal	1	1
	1	4	Kan, Str, Sulph, Tet	1	1
	1	3	Amo, Cefo, Ceph	1	1
Manila	2	0		1	1
Mbandaka	36	0		12	5
Meleagridis	3			2	2
	1	0		1	1
	1	2	Tet, Tris	1	1
	1	3	Sulph, Tet, Tris	1	1
Montevideo	123			20	9
	121	0		20	9
	1	2	Sulph, Tet	1	1
	1	10	Amo, Amp, Cefo, Ceft, Ceph, Chlor, Str, Sulph, Tet, Tris	1	1
Muenchen	6	0		3	3
Muenster	19			3	1
	18	0		3	1
	1	1	Tet	1	1
Newington	12	0		4	3
Newport	59			9	4
	1	0		1	1

Table 4 (*Contd.*)

Serotype	Isolates (*n*)	Antimicrobial resistant (*n*)	Resistance pattern	Pens (*n*)	Feedlots (*n*)
	25	9	Amo, Amp, Cefo, Ceft, Ceph, Chlor, Str, Sulph, Tet	5	2
	22	10	Amo, Amp, Cefo, Ceft, Ceph, Chlor, Str, Sulph, Tet, Tris	6	3
	2	8	Amo, Amp, Cefo, Ceft, Ceph, Chlor, Str, Tet	2	1
	2	9	Amo, Amp, Cefo, Ceft, Ceph, Chlor, Str, Tet, Tris	2	2
	1	11	Amo, Amp, Cefo, Ceftio, Ceftri, Ceph, Chlor, Str, Sulph, Tet, Tris	1	1
	1	10	Amo, Amp, Cefo, Ceftio, Ceftri, Ceph, Chlor, Str, Tet, Tris	1	1
	1	9	Amo, Amp, Cefo, Ceftio, Ceftri, Ceph, Chlor, Str, Tet	1	1
	1	8	Amo, Amp, Cefo, Ceft, Chlor, Str, Tet, Tris	1	1
	1	7	Amo, Amp, Cefo, Ceft, Chlor, Str, Tet	1	1
	1	9	Amo, Amp, Ceft, Ceph, Chlor, Str, Sulph, Tet, Tris	1	1
	1	4	Chlor, Str, Sulph, Tet	1	1
Othmarschen	1	0		1	1
Reading	69			7	2
	3	0		3	2
	63	1	Tet	6	1
	2	4	Chlor, Str, Sulph, Tet	1	1
	1	1	Amp	1	1
Schwarzengrund	1	1	Tet	1	1
Senftenberg	1	0		1	1
Taksony	5	0		3	2
Tennessee	5	0		3	3
Thompson	2	0		2	2
Typhimurium	19			7	6
	6	0		3	3
	8	1	Tet	2	2
	3	5	Amp, Chlor, Str, Sulph, Tet	3	2
	1	2	Sulph, Tet	1	1
	1	4	Amp, Chlor, Str, Tet	1	1
Untypable	15			10	7
	7	0		6	5
	7	1	Tet	5	2
	1	4	Amp, Kan, Nal, Sulph	1	1
Multiple serotypes	2			2	2
Total	702				

Others have reported a higher prevalence of *Salmonella* in the summer months (Jensen and Mackey 1979). The previous study reported by Fedorka-Cray *et al.* (1998) used samples collected only in the fall months of 1994. Although a higher proportion of the samples were culture positive in the current study during the summer months, the prevalence was not sufficiently higher to raise the overall prevalence dramatically when compared with the overall prevalence seen in the previous study of feedlot cattle.

Serotypes

The distribution of serotypes in the current study was similar to that in the previous study from 1994 (Fedorka-Cray *et al.* 1998). However, the third and fourth most common serotypes recovered in the current study were *S.* Reading and *S.* Newport. Both of these serotypes were only recovered from samples collected in the third (April to June) and fourth (July to September) periods of data collection. In addition, the *S.* Newport was recovered from samples from nine pens on four operations from three states and the *S.* Reading was recovered from seven pens on two operations from two states. So despite the fact that the prevalence of these serotypes appeared to be high, they came from a relatively small number of operations. This is consistent with what was seen in a study of *Salmonella* on cow-calf operations in the US where 64·1% of the isolates came from only two of the 187 sampled operations where samples were collected (Dargatz *et al.* 2000). Further, this suggests that there is not widespread clonal dissemination among feedlots.

The five most common serotypes seen among humans in 1999 were *S.* Typhimurium, *S.* Enteritidis, *S.* Newport, *S.* Heidelberg and *S.* Muenchen (CDC 1999). The five most common serotypes isolated from animals from July 1998 to June 1999 were *S.* Typhimurium, *S.* Heidelberg, *S.* Kentucky, *S.* Derby and *S.* Montevideo (Ferris *et al.* 1999). From these serotypes only *S.* Typhimurium (2·7%), *S.* Newport (8·8%), *S.* Kentucky (8·0%) and *S.* Montevideo (12·8%) were seen in the current study. Four isolates (one *S.* Agona and three *S.* Newport) were resistant to ceftriaxone. Some have suggested that ceftriaxone resistant infections among people could originate from cattle, although a definitive link has not been established (Fey *et al.* 2000).

Resistance

One previous study from 1994 has evaluated the antimicrobial resistance patterns of *Salmonella* isolated from faeces of feedlot cattle from the US (Dargatz *et al.* 2001). In that study, most of the isolates (75%, 197/263) were sensitive to all of the antimicrobial tested. The most common resistance seen was to tetracycline (23·2%, 61/263 of isolates) followed by sulphamethoxazole (5·7%, 15/263). Less than 5% of isolates were resistant to all other antimicrobials tested and no isolates were resistant to amikacin, cefotaxime, ciprofloxicin, or gentamicin. Presence of antimicrobial resistance did not appear to be associated with the presence of antimicrobials in the ration the cattle were receiving.

Overall, 62·8% of the isolates were sensitive to all the antimicrobials tested in the panel. This is similar although lower than the 75% of isolates that were sensitive to all antimicrobials tested in a 1994 study (Dargatz *et al.* 2001). There were differences in the two panels used for testing. Among the 16 antimicrobials tested in the first panel, five (cefotaxime, neomycin, pipercillin, ticarcillin and ticarcillin with clavulanic acid) were not represented in the panel of the current study. In addition, five (cefoxitin, ceftriaxone, kanamycin, naladixic acid and streptomycin) were in the current panel but were not present in the panel from the previous study.

In looking at the overall percentage of isolates that are resistant by serotype some serotypes probably appear to be more resistant than others. It may in fact be true that some serotypes are more prone to acquire resistance determinants, but it may also be true that as isolates of a common serotype cluster by pen and likely represent a clone they can and often do share a common antibiogram pattern. The large proportion of certain serotypes that show resistance may simply be an artefact of the clonal nature of these isolates especially when a relatively small number of isolates are represented in the study.

Salmonella Typhimurium DT104 has been a concern in the US and elsewhere (Dargatz *et al.* 1998). In a previous study of faecal samples collected in feedlots no *S.* Typhimurium DT104 isolates were detected (Dargatz *et al.* 2001). In the current study only three of the 713 isolates (0·4%) were identified as *S.* Typhimurium DT104. It would appear that this organism is uncommon in the general population of feedlot cattle in the US. Twenty-eight multiple resistant patterns were identified among the isolates. A majority of the patterns are only represented by one isolate. Among isolates with similar multiple resistance patterns, the similarity of serotypes suggest clonality while the large differences of multiple resistant patterns does not suggest widespread clonal distribution of a single multiple resistance cassette. The patterns with five or more resistance determinants may reflect the presence of an integron (Akkina *et al.* 1999).

Another area of concern in the US has been the emergence of multi-drug resistant *S.* Newport (Dunne *et al.* 2000; Winokur *et al.* 2001; Rankin *et al.* 2002). In this study, 58 of 59 isolates of *S.* Newport were resistant to two or more antimicrobials, mostly five or more. Further studies are needed to evaluate trends over time for prevalence and resistance profiles of *S.* Newport isolates in feedlots and other production systems and the public health arena.

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